Weatherwise

More Rain for New Yorkers?

Will New York Rainmaking Affect New England Rainfall?

The Meteorology of Avalanches - II

Meteorological Aspects of Radio Propagation

This Winter's Weather and Circulation

Vol. 3, No. 2, April, 1950

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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DAVID M. LUDLUM, *Director*
CHARLES A. FEDERER, JR., *Editor*
HANS H. NEUBERGER, *Technical Editor*
D. C. CAMERON, *Research Associate*
ERIC SLOANE, *Art Director*

RAINMAKING — PAST AND PRESENT

ARTIFICIALLY induced precipitation has ever been a subject of human interest. Controversy over its possibilities is spreading from scientific to legal and political fields. The accounts of anthropologists and historians are full of examples of individuals claiming rainmaking abilities and of varied equipment and methods employed in attempts to wring drops of moisture from a reluctant sky.

This time-honored practice, known to primitive tribes, ancient civilization, and modern man, was once very happily called "pluviculture." And a very readable book on the subject was written in 1926 by the eminent American meteorologist, W. J. Humphreys, under the title **Rain Making and Other Weather Vagaries.**

It is timely to note, as Dr. Humphreys reminds us, that the Congress of the United States in 1891 appropriated $9,000 for experiments in rainmaking. Some of the preliminary trials were made near Washington, but most of the work was done in Texas under the direction of General Dyrenforth as "special agent" of the department of agriculture. Operating on the theory that loud noise would induce precipitation, dynamite and hydrogen-oxygen-filled balloons made the sound bursts desired. According to the meteorologists at hand, however, little rain actually fell from the clouds in the vicinity.

There is now a bill before Congress that would appropriate 50 million dollars for experiments to create water by seeding clouds and by the distillation of sea water. Much testimony pro and con is being heard in Washington over the merits of the project, while in New York City plans for actual rainmaking attempts go forward, as described by Dr. Wallace E. Howell, of Harvard University, in the article, "More Rain for New Yorkers?" in this issue of **Weatherwise.**

Dr. Howell will set up control regions and compare the rainfall in his experimental areas with normals for the past 15 years. He has issued an invitation to the Weather Bureau to observe the experiments and make findings of its own. Fred White, assistant in the scientific services section of the Weather Bureau, has been assigned to this project.

Science Service recently quotes the USWB chief, Dr. F. W. Reichelderfer, as saying, "We like the way New York City is going at rainmaking. . . . Dr. Howell seems to be going at it from the statistical approach and we like this."

It was at New York at the recent meeting of the American Meteorological Society that the peak in the controversy over rainmaking was reached, and the chief argument centered on

(Continued on page 46)

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Cover: Rainmakers visit New York City's Esopus watershed in the Catskill Mountains during an inspection tour on March 17th. Left to right are Stephen J. Carney, New York water commissioner; Chief Engineer Edward J. Clark; and Dr. Wallace E. Howell, Harvard University. Dr. Howell rejected Overlook Mountain as a site for rainmaking headquarters. Wide World photograph.

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Dr. Wallace E. Howell and New York City officials confer with Capt. Gustav Crawford at Floyd Bennett Field, Brooklyn, N. Y., March 20th, in a briefing for police department airplane pilots in the proposed rainmaking operations. Left to right: Dr. Howell; Mayor William O'Dwyer; Stephen J. Carney, water commissioner; Capt. Crawford, chief of the police department's aviation division, and Edward J. Clark, chief engineer for the department of water supply, gas and electricity. Wide World photograph.

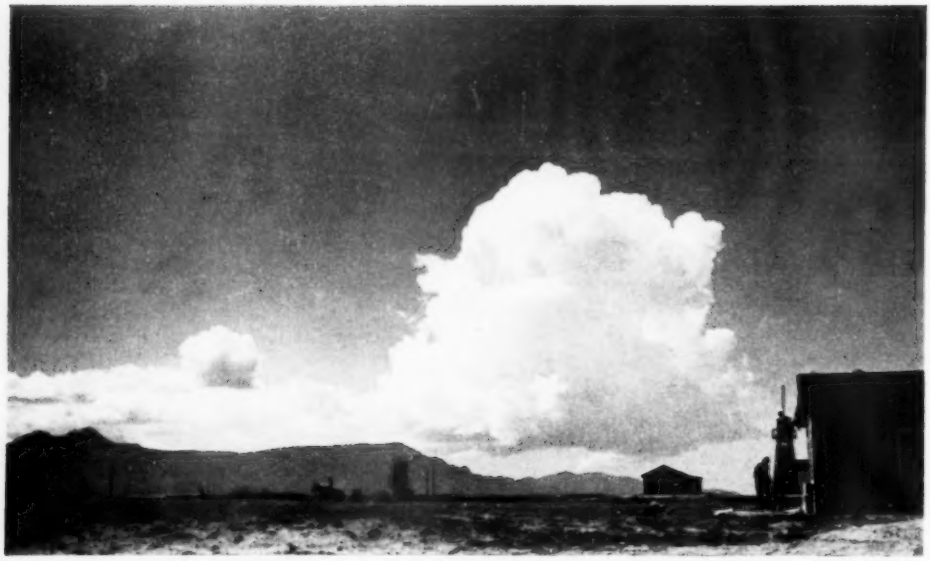
More Rain for New Yorkers?

WALLACE E. HOWELL, HARVARD UNIVERSITY

THREE TIMES in the past hundred years, the water consumption of New York City has doubled. At the present time the demand is increasing at a rate that will again double the consumption of water in another 30 years. Thus, to meet that demand will require increasing the supply to 16 times the total demand of a century ago. Obviously, such a geometrical progression meets ever-increasing difficulties in the greater distance of available sources of potable water, and in the greater area of the watershed from which it must be drawn. Only improvements in construction engineering make the feat even remotely possible.

Like nearly all such emergencies, the water shortage in New York City at the present time has had not one but a succession of causes. Principal among these is the late world conflict, for the war not only forced postponement of the city's normal program for expanding its water supply, but also it turned the curve of urban population even more sharply upward.

For several years, New York City's demand has been greater than the dependable yield of its water supply system, and an earlier water shortage has been avoided only because the rainfall did not drop far below average at any time. Last summer, despite the fact that on June 1st the reservoirs had been full to overflowing, a season of record heat and protracted drought set the stage for trouble, while water consumption in the city rose to new heights, on the hottest days, of nearly a billion and a half gallons in 24



This was the first cloud to appear in a previously cloudless sky near Albuquerque, New Mexico, in a seeding experiment conducted by Project Cirrus. At 10:06 a.m., July 21, 1949, a few hours after seeding had begun, the cloud developed an area of rain of about one square mile as indicated by radar. At 10:10 the rain area had expanded to four square miles, thunder was heard and lightning flashes were visible. General News Bureau photograph.

hours. The reservoirs were rapidly depleted, and when autumn rains failed to replenish them an energetic conservation program was found necessary, and legal measures were taken to limit wasteful industrial uses of water.

Despite about five weeks of heavier-than-average precipitation over the watersheds, at the present writing (the last week in March) the reservoirs are only slightly more than half full and nearly 40 per cent of capacity below last year's levels at the same season. Record rainfall would be required for the coming two months if New York City — with a population that is still growing and a potential water demand greater than ever — were to enter the summer with as great a water reserve as it had last June.

This is the background of the city's decision to undertake an experiment in the artificial stimulation of precipitation. The aim is twofold: to do what can be done to replenish the water supply as soon as possible, thus avoiding the necessity of continuing the conservation campaign through the summer months, when it would cause far more hardship than it has brought about in winter; and to find out to what extent the dependable yield from the city's billion-dollar investment in water supply works might be increased. On the one hand, operations will be undertaken as frequently as possible to attempt to increase the precipitation, paying great attention to the possibility of improving results by acquiring new skill, and on the other hand the precipitation will be carefully studied to determine what increase, if any, will have been effected by artificial means.

Insofar as possible, the operation will be carried out using the facilities that the city already has. The airplanes of the police department will be used to drop granulated dry ice or spread silver iodide smoke, and smoke generators on the ground will be operated by regular employees of the department of water supply. Much of the statistical work necessary for evaluation of the results will be carried out in this same department.

The U. S. Weather Bureau will co-operate by providing detailed weather forecasts for the operation and by contributing to a detailed study of the natural distribution of pre-

At 10:32 a.m., July 21, 1949, the cloud pictured opposite had more than doubled in size to that shown above. Showers and rain were falling to the ground, as indicated in the gray areas in the center background. Dr. Irving Langmuir, consulting General Electric scientist, stated that eventually this seeding operation produced 320 billion gallons of rain over half the state of New Mexico. General News Bureau photograph.

cipitation over the Catskill region. If possible, radar observation will be afforded, perhaps through the co-operation of the armed forces, possibly by the incorporation of existing radar stations of the Air Weather Service into the operational scheme, or by the lending of equipment to the city.

New York has embarked on an experiment in an area of science still subject to currents of controversy. Some previous experimenters have reported startling results, others find that almost nothing of significance can be expected. There is unanimity in the counsel of caution, in both the conduct and the evaluation of the experiment. The results made available to meteorological science through the experiment may help to narrow the area of controversy and will constitute a severe test of the practicability of artificial interference with natural precipitation.

The services of Dr. Howell, present director of the Mt. Washington Observatory, have been engaged at the rate of 100 dollars a day to make a survey of artificial rainmaking possibilities in the Catskill watershed. In collaboration with Dr. Howell, a board of six consulting physicists drew up a report outlining a plan of action to be put into effect immediately.

The striking force of the rainmaking battalion is reported to be four mobile units, two on the ground and two in the air. The airplanes, police department amphibians based on Floyd Bennett Field, Brooklyn, will be in constant readiness to make the one-hour trip to the watershed, where they will be directed by radio from the ground at the Catskill rainmaking headquarters. In an emergency, the planes could land on the waters of the reservoirs.

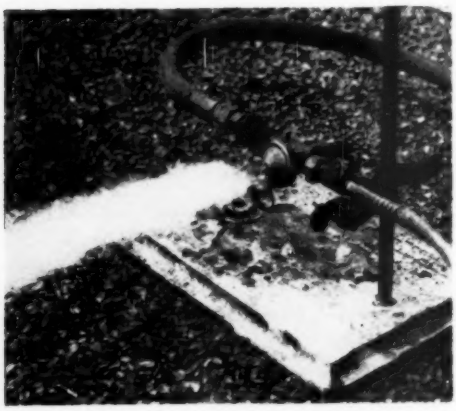
Two light trucks can be used when the weather is too rough for flying, carrying silver iodide smoke generators to the proper locations for seeding operations. ED.

WILL NEW YORK RAINMAKING AFFECT NEW ENGLAND RAINFALL?

CHARLES F. BROOKS, HARVARD UNIVERSITY
DIRECTOR, BLUE HILL METEOROLOGICAL OBSERVATORY

A RECENT PRESS REPORT, to the effect that any success New York may have in augmenting the natural precipitation over its reservoirs would reduce the rainfall over Boston's reservoirs, has immediately interested the New England Council. The general storms that bring precipitation to New England often come across New York first. It is thought that if the water content of the storm clouds is reduced by artificial means over New York less must be left for New England.

Obvious and uncontrovertible though this reasoning seems, however, it is largely wrong. A storm is not like a huge, leaking bag of water that is flown across the landscape. At any one time, the amount of water present in a storm cloud would rarely be enough to make an inch of rainfall if it were *all* brought down to the ground. Yet as a storm travels it keeps on raining indefinitely. Indeed, as a storm from the interior approaches the Atlantic seaboard the rainfall it produces almost invariably increases. It increases in spite of having left a lot of rain behind!



The silver iodide smoke generator, developed by Dr. Bernard Vonnegut, of General Electric Company, and used in the seeding operations conducted by Project Cirrus last July in New Mexico (see preceding pages). In operation of the generator, silver iodide suspended in a solution of acetone is burned in a hydrogen flame, which vaporizes the silver iodide. This vapor solidifies into extremely fine particles, less than a millionth of an inch in diameter, which rise into the sky to furnish condensation nuclei. General News Bureau photo.

What happens is that the storm is a great rainmaking machine. The raw material enters the front side in the form of water vapor from the ocean to the south of us. This vapor is lifted when it meets obstructing masses of colder air and when the winds pushing in from all sides toward the low pressure storm center converge and squeeze one another upward. The ascent of the air brings it into higher elevations where the atmospheric pressure is less, and this allows the air to expand. The expansion cools the air by the work done, and soon the vapor present begins to condense and rain to form. The rain then falls to the ground, usually within a few tens of miles of where it formed. If there is artificial stimulation the natural process of rain formation is simply intensified by inducing extra cooling or by providing fewer centers of coagulation so that each raindrop becomes larger and therefore falls faster, bringing more of the condensed water to the ground.

Thus, if more of the vapor and cloud in the storm when it is over New York is brought down there, there will be less of these only in that area where the air goes after passing over New York, which is usually to the northeast, or across western Connecticut, western Massachusetts, and southern New Hampshire. The deficiency, however, such as it would be, should be in the upper clouds, whence very little of the precipitation comes. The reduction from the loss of an extra tenth of an inch of rainfall artificially produced on New York's reservoirs, a rather small area, would be spread through such a large volume of the upper air over New England as to represent no more than a thousandth of an inch worth of precipitation anywhere in these states. This is a matter of no concern, for the general rain machine, using great quantities of new vapor direct from the ocean, would go on

Dr. Irving Langmuir, associate director of the General Electric Company's research laboratory, and Dr. Bernard Vonnegut (center) watch the making of a miniature snowstorm in a home freezer in the laboratory. Dr. Vincent J. Schaefer, cloud-seeding expert, first produces a supercooled cloud in the freezer by blowing in his breath. A few small particles of dry ice, dropped into the freezer, then turn the supercooled cloud into snow. General News Bureau photograph.

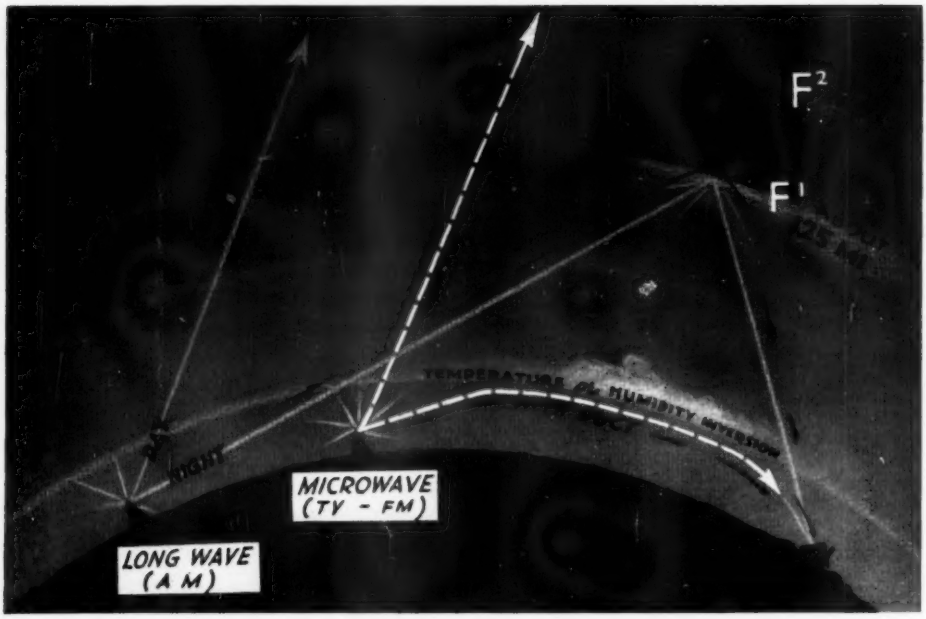
producing over New England as if nothing had happened over New York.

If operations over New York should succeed in producing a thunderstorm by stimulating the growth of large clouds that otherwise would not have rained or rained only a moderate amount, there is a chance that the storm, once started, would be self-perpetuating for a few hours. In the course of that time it would put a lot of the vapor over New England through the "wringer" and increase the rainfall of New England by giving us a shower we would not otherwise have had. The chances of doing this, on a small scale, at least, seem likely to increase New England's rainfall more than the loss of vapor, already described in a general storm, would reduce it.

In conclusion, it seems well to point out that artificial stimulation of rainfall is still very much in the experimental stage. While some experimenters have apparently produced more rain than others, agreement among meteorologists seems general only on the following points: 1. Precipitation can be produced artificially. 2. The amount that can be produced varies directly in proportion to the tendency toward natural rain. 3. Much more experimenting still needs to be done to compare precipitation from treated clouds with that from similar untreated ones in the same vicinity at the same time. 4. Until it has been proven that substantial amounts of precipitation can be added to natural rains, there seems no point for any region to become concerned over any operations elsewhere having an adverse effect.

SEVERE FREEZE IN ARIZONA

Early in March, an extremely cold air mass, pushing directly south from British Columbia where temperatures of −56° F. were recorded, traveled all the way south to the Salt River Valley in south-central Arizona and caused great losses among the citrus fruits there. Louis R. Jurwitz, official in charge at Phoenix, stated that the freeze, lasting four days, was the most severe in the area since 1937. Estimates of damage to fruit ran as high as 90 per cent. All countermeasures, such as smudging and warm water flooding, proved ineffective because the clear nights of March 5th and 6th caused great loss of heat by radiation. The temperatures in the valley ran as low as 15°.



Microwave transmission is like long-wave radio by day — mostly point to point. A temperature or humidity duct can affect the microwave signals, however, in a manner similar to that of the F layers in the ionosphere on radio waves at night. Drawing by Eric Sloane.

METEOROLOGICAL ASPECTS OF RADIO PROPAGATION

THEODORE W. GIBSON, JR., PHILCO CORPORATION

DURING THE RECENT WAR, radio engineers became aware of the effects of weather conditions on the propagation of radio waves used for radar and other microwave electronic devices. The meteorologist was called in to interpret observed variations in ground-echo patterns and to explain why airplanes aloft were spotted by radar at great distances on some days and not on others.

With the return to peacetime activities, the radio technician still sought the weatherman's aid to explain why television and FM radio signals, like radar, were received at great distances, beyond the theoretical range of the instruments. For example, he wanted to know why television signals from a station in New York City could be received rather well in Philadelphia (90 miles distant) during the morning and then faded out completely in the afternoon, only to return toward mid-evening.

For an understanding of the effects of weather on the propagation of radio waves, engineers considered that all high-frequency radio signals (television, FM, and microwaves) generally traveled in straight lines in a manner identical to light. Then it was necessary to study the meteorological effects on light waves and, by analogy, to interpret for the radio services. Weather conditions have long been known to affect light waves and create mirages and looming. Mathematical equations indicated that light waves were curved toward the earth's surface if there were either a rapid increase of temperature with height (nocturnal temperature inversion) or a rapid decrease of moisture content with height (cold air over warm water).

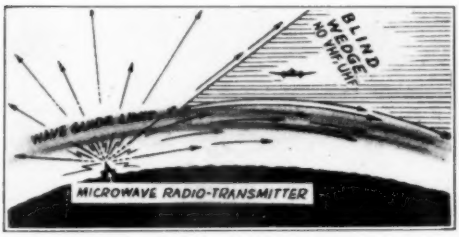
Consider an outbreak of cold, dry polar continental air moving off the East Coast to the Gulf Stream. The surface layer becomes very moist and a steep humidity gradient is formed. The surface atmospheric region becomes a *wave guide* in which horizontal light rays are trapped and continuously curved, to

remain within the surface layer for many miles.

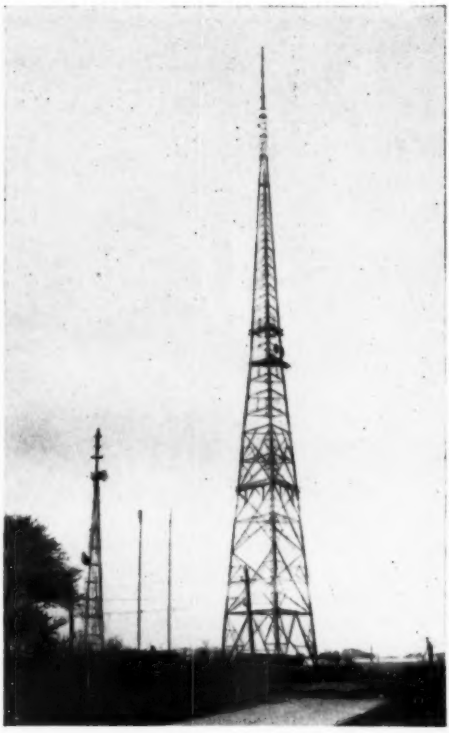
After the meteorological conditions were determined for the bending, or refraction, of light waves, analogous high frequency radio wave behavior was studied under similar lapse rates of temperature and humidity. Significant quantitative relationships were observed. The reality of the trapping of microwave radio signals within particular low-level atmospheric zones was established. These zones were called meteorological *ducts* and the forecasting of the temperature and humidity conditions favorable to duct formation required a new type of forecaster, the radio meteorologist.

During the war the meteorologist's problem was twofold: to analyze effects of various types of air masses over water, and to determine the effect of temperature inversions and humidity lapse rates at different levels aloft over land. The over-water problem proved to be essentially a situation of cold air over warm water in which the surface layer became a microwave guide or duct. It was found that at more than 25 miles or so from the transmitter site a blind wedge developed within which no microwave radio signals were present.

The over-land situation, on the other hand, required a method of evaluating composite upper air data to determine the intensity of lapse rates and inversions aloft. The predominant factor to define a wave guide at any level was a pronounced moisture lapse rate, such as a cloud deck within which a rapid decrease in moisture content occurred. Studies verified that temperature inversions, developed close to the earth's surface by nocturnal cooling, created a mild wave guide condition.



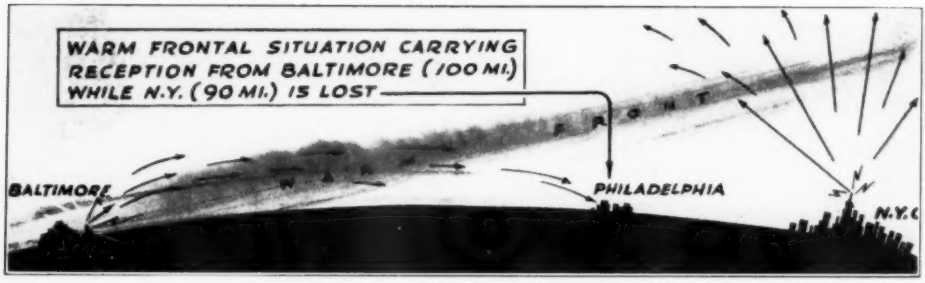
The wave guide effect in a duct on the transmission of microwave radio signals, showing the blind wedge created above the duct. Drawing by Eric Sloane.



The new transmitting tower of WPTZ, the Philco television station at Philadelphia, which is 549 feet high including the antenna. The old tower, seen in the background, was 172 feet high with its antenna. The new tower and a better transmitter have increased the output of WPTZ four times, although tests have not been completed to show the increase of range in miles with the new tower. Philco Corporation photograph.

Interpretation of the meteorological effects for postwar use became a simple matter after it was determined that television and FM radio signals were influenced in the same manner as radar and other microwaves. Thus the irregular reception of New York television signals in Philadelphia, mentioned earlier in the article, was explained as a nocturnal temperature and moisture duct that was destroyed during the morning and reformed after sunset in the evening.

For the last few years, the National Bureau of Standards has been furnishing monthly predictions of skip effects for long-distance



The effect of the passage of a warm front on the transmission of microwave signals. The moist region in the warm front furnishes a duct for transmission of TV beyond the theoretically expected line-of-sight limit. Drawing by Eric Sloane.

communication in the short-wave radio spectrum for various periods of day and night. The predictions, however, are based on the effects of upper-level electronic layers (between 50 and 200 miles aloft) rather than on surface meteorological variations.

In general, it may be stated that inasmuch as temperature inversions have shown only a mild effect on wave guide development, the meteorological phenomenon of interest for abnormal ranges of television and FM signals is a pronounced moisture lapse rate at or near the earth's surface. The accompanying illustration presents an afternoon warm front situation that permitted Philadelphia to receive television signals from Baltimore, channel 13, 100 miles distant, although New York, channel 13, 90 miles distant, could not be received. The following day the warm front lay a short distance north of Philadelphia, and the situation was reversed; there was satisfactory reception from New York channels and nothing from Baltimore or Washington.

Within a well-defined cold air mass reception of both New York and Baltimore channels in Philadelphia is favored by a well-defined temperature inversion with an associated humidity lapse rate. The combined temperature and humidity effects create an intense wave guide which causes the transmitted signals to curve back to the earth from the 5,000- to 10,000-foot levels.

The most interesting event of late occurred during an afternoon in August, 1949. The Philadelphia area was receiving weak signals from New York City, channel 4. With an easterly flow, a precipitation area moved over Philadelphia from New Jersey and the ocean. As the advancing precipitation zone crossed the New York-Philadelphia path, it erased the wave guide condition, and the consequent drizzle created a uniform lapse rate of temperature and humidity. At the television receiver location, signals from New York faded abruptly in a matter of several minutes, followed 10 minutes later by the drizzle conditions.

Unusual propagation of television waves has recently been occurring in central New Jersey, where the normal reception of a New York City station has been blanketed by the abnormal reception of a Baltimore station transmitting on the same channel. Formerly, it was thought that a 200-mile geographical separation of television stations would enable them to operate on the same channel, but the continual occurrence of duct conditions has extended the range of stations far beyond the line-of-sight limit.

Meteorological conditions have thus caused the Federal Communications Commission to revise completely its original plan for the granting of station licenses. At the present writing, granting of new permits has been frozen pending further study of wave propagation.

Reports of anomalous propagation are continually received and published by such periodicals as *Radio-Electronics*. In the summer of 1948, Argentinian microwave signals were received in New York, and a Chicago microwave station interfered with British television transmission.

The book, *Radio Wave Propagation*, by Charles R. Burrows and Stephen S. Atwood, New York, 1949, is suggested for further reading on this subject.

A windslab avalanche caused by a stray dog, whose pawprints can be seen. Photograph by Dr. Paul Gut, chief of the Swiss Rescue Division. Reproduced from *World Ski Book*, edited by Frank Elkins and Frank Harper, courtesy Longmans, Green and Co., Inc.

The Meteorology of Avalanches - II

MARY-REBECCA CREGAR AND WILDE R. MELLONCAMP

AMATEUR WEATHERMEN OF AMERICA

NO MATTER how much a meteorologist might know about weather principles, he would be unwise to forecast for a given locality before he knew the peculiarities of weather behavior in that area. Avalanches, too, have their broad common causes; these result from the interplay of temperature, humidity, and wind. In our February article we discussed some of the general principles that hold for all avalanches, everywhere. As is true with weather, however, local conditions govern the characteristics of local avalanches.

Our observations made at Aspen, Colorado, in 1948-49, showed a special type of snow forming at the ground which played a major role in avalanche formation there. In the autumn the first snows fell on unthawed or slightly frozen ground. Such snows, if over eight inches deep, keep the ground from hard freezing all winter long. If cold weather sets in after such a fall, a great temperature differential occurs between the ground and the snow surface. The snow temperature will be close to freezing at the ground, and near $-10°$ centigrade at, say, 10 inches above the ground.

This condition augments sublimation, which favors the growth of deep frost, or *swim-snow*: large, hollow, goblet-shaped crystals with little cohesion. Once started, a layer of swim-snow can increase in depth throughout the winter if conditions are favorable, and the extent to which these crystals form has an important bearing on winter-long avalanche danger. When enough records have

been made, it will be possible to estimate under what conditions a swim-snow base is most apt to give way.

Swim-snow builds more readily in wooded areas, because fallen branches and rubble allow less settling and more air circulation. At Alta, Utah, wooded areas are reasonably safe,

A depth-hoar or swim-snow crystal, enlarged about 12 times.

while at Aspen they can be more dangerous than an open slope. The swim-snow type of crystal forms to a greater extent on a northern or eastern slope.

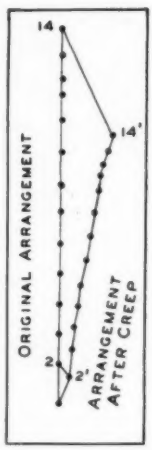
Alta is a fine example of how meteorological and avalanche data can be correlated to achieve adequate avalanche control. Through study of records covering a 10-year period,* it has been possible to establish certain definite danger signals for that limited area. For instance, seven inches of wet snow or 14 inches of dry snow, or a wind of 10 miles per hour, means that it is time to check the rest of the weather picture (temperature, expected temperature change, rate of snowfall, and so on) and to decide whether to close the trails and the road. Avalanches at Alta follow storm cycles. As a rule, storms bring a great amount of snow, and the winter accumulation is deep. The danger at Alta results mainly from slab formation and the accumulation of snow to such a depth that its weight overcomes its cohesive strength.

*These records were kept by the U. S. Forest Service, and an analysis of them was made by Ranger Monty Atwater, in charge of avalanche control at Alta.

Slab formations, which occur plentifully at Alta, present a peculiarly insidious hazard, because their instability results not from readily recognized overweighting or sharp temperature changes, but from tensions that develop imperceptibly within the snow.

When snow lies on flat ground, the weight of the snow presses straight down. However, when snow rests on a slope, the weight presses partly inward toward the hill and partly valleyward down the hill. The steeper the slope the stronger the downhill pressure. This results in a force which makes the snow "creep" downhill like thick molasses. It may reach a speed as great as 10 inches a day.

It has been shown by experiment that the upper layers tend to creep faster than the lower ones. If there is good anchorage, the lower layers may remain stationary. To show this, a hole was bored vertically in the snow on a slope and a series of ping-pong balls was dropped in with sawdust spacers. After some 80 days a profile was made of the area, with the results shown in the diagram.



The drift of ping-pong balls with the snowcover, from experiments conducted at Davos, Switzerland.

Other factors being equal, this creeping action speeds up along a sudden steepening of the hill (convex being more effective than concave) and slows down as the hill flattens out. As soon as the rate of creep becomes uneven in a cover, tensions develop. Where the speed is increasing, a stretching or pulling action comes into play — negative tension. When the speed is slowed down, a shoving or positive tension is developed.

The point of negative pressure is of more interest in the study of avalanches. Since the snow is being stretched, it is thinned and weakened until it can reach the breaking point. A zone of stretching is an ideal one in which to place explosives for loosening avalanches artificially. If you have to cross a dangerous slope, the top of such a zone is obviously the safest place.

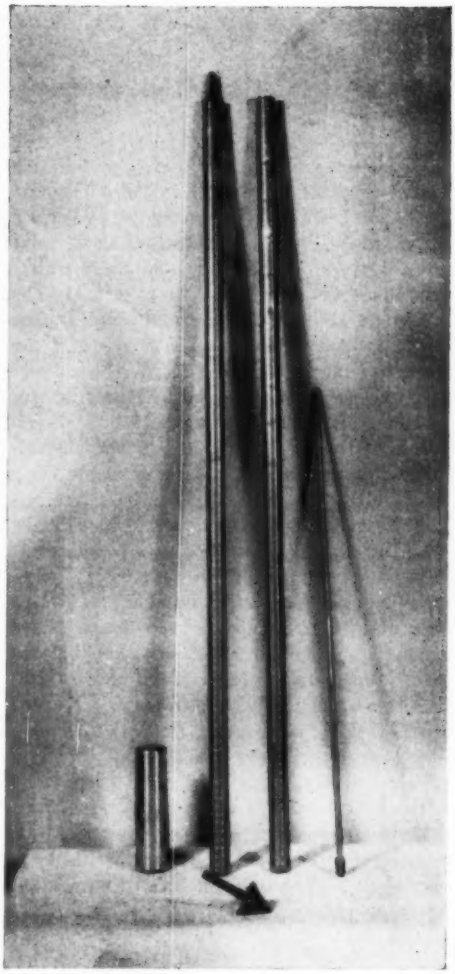
Back to meteorology, we find again that temperature, temperature change, wind action, type of snow, and density affect those properties of snow (its plasticity, viscosity, and break point) which allow it more or less to withstand tensions. Wind, of course, is especially important because it causes slabbing — masses of snow packed into brittle sheets that adhere indifferently to the settling snow beneath them, and that, when stretched, have a low resistance to shock (the shock of a skier's weight, the footsteps of an animal, a falling chunk of snow or rock, or even a shout).

Avalanche study and forecasting rests squarely on the accumulation and analysis of all available data. As has been discussed, meteorological factors play an important part in the volume, distribution, and consistency of the snow; records must be kept of such factors as wind velocity and direction, precipitation, temperature, humidity, barometric pressure, and so forth.

Secondly, a check must be kept on the surface layer of the snow. It will eventually become a hidden layer; all that can be known about it while it is on the surface helps to estimate its behavior when it is invisible. What type of snow is it — loose, crusty, wet, frozen? Is it settling into a cohesive layer? Is it drifting and forming slabs? When new snow falls, does it adhere well to the old surface layer?

Although weather and surface observations give a clue to the condition of the snow deep within the cover, they by no means provide sufficient information to estimate avalanche hazard. The only way of finding out what is down there is to dig and jump in.

Following the technique used by Swiss observers, we made weekly diggings in a test or control field in a level, protected clearing. Our procedure was to dig a trench to the ground, large enough to stand in, and with one side shoveled smooth to make the layering (the snow's profile) show up. We made notes on the depth and consistency of each layer (size of grain, type, adhesion between layers, and estimated hardness). The resulting information could not, of course, be assumed to apply exactly to the whole area. But if, for instance, we found a ground layer of swim-snow which increased from week to week, the chances were strong that a ground layer of swim-snow was forming elsewhere.



The ram made by the authors for use in avalanche studies. It consists of a cone-shaped tip for penetrating the snow, a calibrated rod (in two sections), and a weight that is allowed to drop from a known height. Hardness and softness of snow-cover layers are measured by the relative penetration of the ram through each layer.

This is cold work, and not conducive to the very detailed observations needed to build adequate statistics. Vincent Schaefer, in the course of his work on the formation of snow and rain, has developed a plastic with which it is possible to make a perfect three-sided

(Continued on page 46)

This Winter's Weather and Circulation *

WILLIAM H. KLEIN, EXTENDED FORECAST SECTION
UNITED STATES WEATHER BUREAU

THE AVERAGE TEMPERATURE and precipitation anomalies observed in the United States during the past winter (from December 1, 1949, to February 28, 1950) are portrayed in Fig. 1. Temperatures were above the seasonal normal in most of the country, with the greatest positive departures in the South and East. Below normal temperatures were confined to the Pacific states and the northern Great Plains, and the maximum negative anomaly was observed in Montana.

Winter precipitation exceeded seasonal normals along most of the northern and western borders of the United States and in the Ohio and Mississippi valleys. Elsewhere precipitation was generally deficient. More than twice the normal amount of precipitation fell in Indiana and portions of eight neighboring states, resulting in serious floods on the lower Ohio and Mississippi rivers and their tributaries. On the other hand, less than half of normal precipitation fell in most of the Carolinas, Georgia, and Florida, as well as portions of Arizona, Nevada, and the western plains.

These weather anomalies were closely associated with equally well-marked anomalies of the winter mean circulation. Average winter heights of the 700-mb surface were above normal in the eastern and southern United States and strongly below normal in the Northwest, as shown in Fig. 2. As a result, the direction of mean air flow relative-to-normal (assumed to be parallel to the dashed isopleths of equal 700-mb height anomaly) was from the southwest over most of the United States. As previously noted for five-day and monthly means (WEATHERWISE, February, 1950, page 16), the area in which surface temperatures were warmer than normal was characterized by above normal heights and/or southerly wind components relative to normal at 700 millibars; while the region of subnormal surface temperature had negative height anomalies and/or northerly wind components relative to normal.

Most of the heavy precipitation was located in the region of strongest southwesterly flow, near the point of inflection between the trough and the next downstream ridge. Stronger-than-normal westerly wind components produced heavy precipitation along most of the West Coast, but created a rain shadow east of the Rocky Mountains. In the Southeast, precipitation was generally light because of the dominance of anticyclonic conditions and positive height anomalies aloft.

Some of the observed weather anomalies can be further clarified by the winter mean-sea-level map, Fig. 3. Outstanding features in North America are the abnormally strong polar anticyclone, extending from Alaska southeastward into the Dakotas, and the anomalous westward protrusion of the Bermuda high into the eastern United States. As a result of the blocking action of these anticyclones and the steering imposed by the circulation aloft, the mean storm path was displaced south of its normal position in the western United States and north of normal in eastern portions. (See the *Monthly Weather Review* for the individual storm tracks.) Thus, cyclones from the Gulf of Alaska, which usually cross western Canada, moved generally southeastward along the Alaskan coast through Washington, Idaho, Wyoming, and Nebraska. North of this track easterly surface wind components (both absolute and relative-to-normal), intensely cold arctic air, and heavy snows prevailed in the Dakotas, Minnesota, Montana, and even Washington. South of the cyclone track, anticyclonic conditions, light precipitation, and milder Pacific air prevailed over most of the Southwest. Throughout the eastern United States surface wind components were more southerly than normal, and large quantities of warm air from the Gulf of Mexico were transported far northward.

This winter's circulation features in the United States were only part of a larger system of planetary waves in the westerlies. In fact, the largest anomaly of 700-mb height observed in the Northern Hemisphere this winter was located in the Bering Sea (see Fig. 2). The effects of this anomaly upon the

*A similar discussion of the weather and circulation of each month considered separately is being published in the *Monthly Weather Review*.

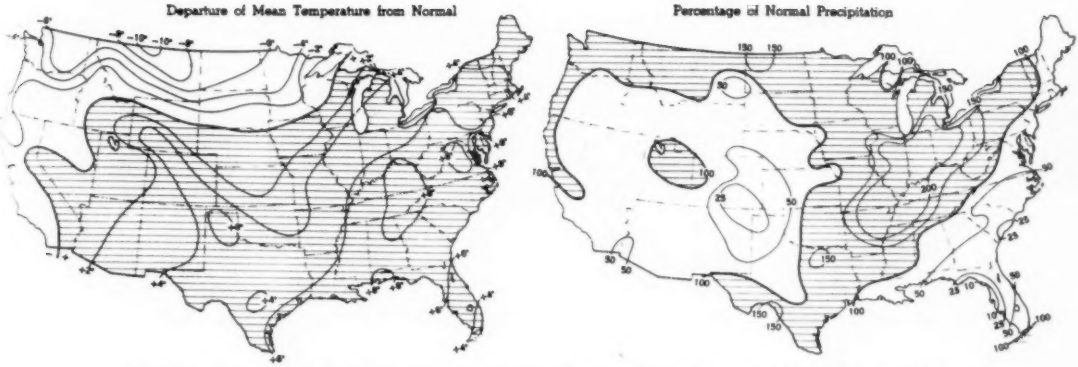


Fig. 1. Average anomalies in temperature (degrees Fahrenheit) and in precipitation for the winter of 1949-1950 (December through February). From the *Weekly Weather and Crop Bulletin* for the week ending March 7, 1950.

circulation and weather of the United States were undoubtedly of utmost importance and will require further study. It is interesting to note that the location of the principal 700-mb troughs and ridges in the entire Northern Hemisphere during this winter was similar to that of last winter. For a discussion of last winter, see an article by the author in WEATHERWISE for April, 1949.

As a result, during both winters temperatures were abnormally cold in western Canada and the northwestern United States and abnormally warm in the eastern United States, western Europe, and Mexico; while precipitation was generally heavy in the Ohio and Mississippi valleys and deficient in southern Europe and the southeastern United States. Most of the centers of 700-mb height anomaly in the eastern Pacific and North America, however, were farther north and more intense this winter than last. Consequently, westerly wind components (relative to normal) produced wetter weather on the Pacific Coast of the United States and warmer drier conditions in the Southwest during this winter than were experienced last winter, when more easterly wind components prevailed. On the other hand, the greater intensity and northward displacement of the Bermuda high this winter made it one of the warmest on record in large portions of the eastern and southern United States.

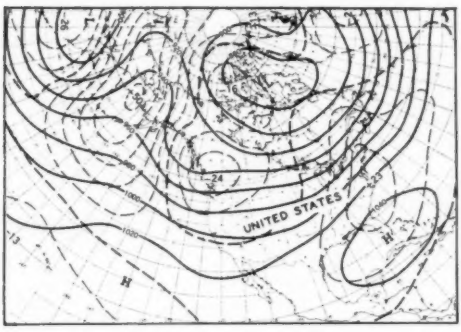


Fig. 2. Observed mean 700-mb chart for the winter of 1949-50 (December through February). The solid lines are contours at 200-foot intervals. Departures from normal of 700-mb height at 100-foot intervals are shown by dashed lines with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet. USWB chart.

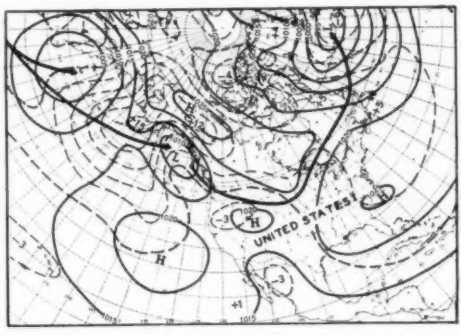


Fig. 3. Observed mean-sea-level chart. Solid lines are isobars at 5-mb intervals. Departures from normal of sea-level pressure at 3-mb intervals are shown by dashed lines with the zero isopleth heavier. Anomaly centers and contours are labeled in millibars. Solid arrowhead curves represent idealized mean cyclone tracks. USWB chart.

FORECASTING THE WEATHER

The Relationship of Temperature and Precipitation over the United States to the Circulation Aloft

DONALD E. MARTIN AND HARRY F. HAWKINS, JR.

EXTENDED FORECAST SECTION, UNITED STATES WEATHER BUREAU

TEMPERATURE PATTERNS OVER THE WESTERN UNITED STATES IN WINTER

IN THE PREVIOUS ARTICLE it was shown that there are certain key areas for determining the surface temperature in the central and eastern United States from the circulation aloft. One might reasonably wonder whether these same areas are equally important for temperatures in the West. In order to answer this question, let us consider the topography of the United States. In the relatively level country east of the Rocky Mountain range there is a free interplay of air masses from polar continental and tropical maritime source regions. The Rockies, however, tend to shunt the cold continental polar air from northwest Canada to the east and southeast and to retard or deflect the eastward-moving warmer Pacific air. The presence of this high land barrier means that the air currents invading western sections of the country are usually different from those in the East. Hence it is expected that the critical areas for relating surface temperature to upper-level circulation patterns would be different in the western than in the eastern United States.

In the February issue, we found that the points important for determining the surface temperature at Evansville, Indiana, were located near 60° north and 130° west and near Evansville itself. The height anomalies at these points measure the direction and intensity of the general circulation affecting Evansville's weather. Another viewpoint, perhaps oversimplified, is that the northern point measures the strength and availability of polar continental air, while height anomalies near the station indicate the relative importance of the opposing warm air from the Pacific Ocean or the Gulf of Mexico. What, then, are the key points which act as control valves for the cold and warm air masses that invade the western sections?

Let us explore the problem further by examining the surface temperatures at Eureka, California, in their relation to the upper-level flow patterns as represented by the 700-mb chart. Typical 700-mb patterns associated with extreme cold and extreme warm surface temperatures at Eureka are given in Figs. 1a and 1b, respectively. These charts show that low temperatures are associated with the northwesterly upper-level circulation which emanates from a ridge in the northern Pacific. This provides a long sweep of relatively cold north Pacific air from the Gulf of Alaska into the trough in the southwestern United States. In the case of extreme warmth at Eureka (Fig. 1b) the 700-mb flow pattern shows southwesterly circulation representing a long trajectory of air over relatively warm southern Pacific waters.

By subtracting normal 700-mb values from the patterns shown in Figs. 1a and 1b, we obtain sets of lines giving 700-mb height departure from normal (Figs. 2a and 2b). As mentioned in the preceding article, this procedure permits a rapid comparison of a given circulation pattern with the one normally expected at that

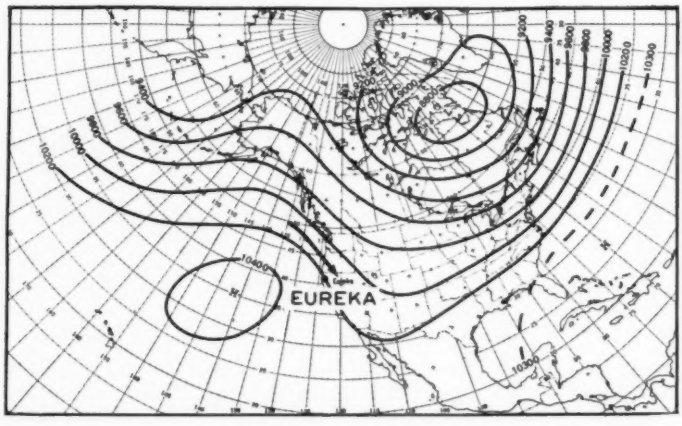


Fig. 1a. Typical 700-mb chart associated with cold surface temperatures at Eureka in the winter season. The arrow indicates the upper-level wind direction as shown by the contour lines.

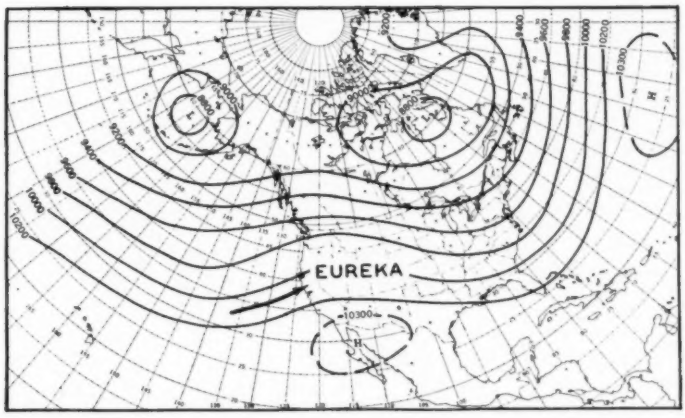


Fig. 1b. Typical 700-mb chart associated with warm surface temperatures at Eureka in the winter season. The arrow indicates the upper-level wind direction as shown by the contour lines.

season of the year. Thus, in Fig. 2a the cold pattern is associated with large positive height departures from normal in the southern Gulf of Alaska. On the contrary, heights well below normal in the same location correspond to warm surface temperatures at Eureka (2b). An extremely important factor for relating the upper-air circulation pattern to the surface temperature at Eureka is the variation of the height of the 700-mb surface in the Gulf of Alaska — over 1,000 miles away! This point is so situated that it indicates the way in which cold or warm air currents are affecting Eureka.

Again from Figs. 2a and 2b, it is seen that the 700-mb height anomalies over the Southwest depart in opposite directions from the normal for the cold and warm situations. This is apparently another key area for estimating Eureka's temperature. The extent to which the height anomalies in the Gulf of Alaska and in the southwestern United States are in or out of phase determines the degree of temperature anomaly at Eureka. In the case of the cold circulation (Fig. 2a), both factors are operating to produce a strong northeasterly deviation of the wind direction from normal, as shown by the lines of equal height anomaly. Here the below normal heights over the Southwest contribute an additive effect to the positive anomalies in the Gulf of Alaska. On the other hand, heights below normal in the Gulf of Alaska are aided by strong positive anomalies over the Southwest to produce strong southwesterly wind components relative to normal at Eureka.

Since the sign and intensity of the height anomalies in the Gulf of Alaska and in the southwestern United States indicate the direction and strength of air flow at Eureka, a simple forecast graph based on these two parameters affords a method for the rapid evaluation of the effect of the upper-level circulation on the surface temperature (at Eureka). The graph is similar to that obtained for Evansville and consists of an analysis of observed surface temperatures as a function of the 700-mb height anomalies in the southern Gulf of Alaska and in the Southwest (Fig. 3). The sloping lines of equal temperature anomaly indicate the relative importance of each

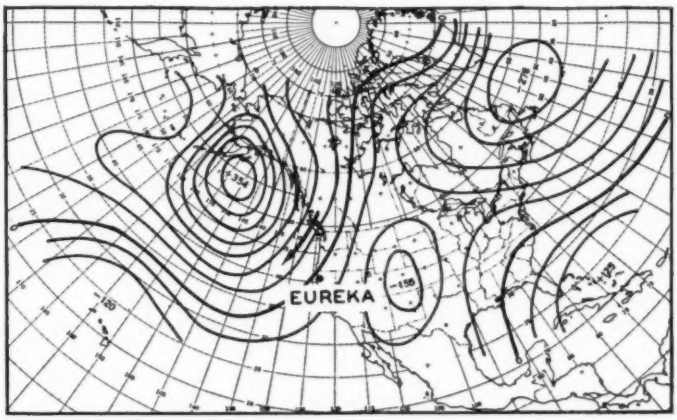


Fig. 2a. 700-mb height departure from normal associated with cold surface temperatures at Eureka. This chart was obtained by subtracting the normal 700-mb height values from the pattern of Fig. 1a. The arrow indicates the deviation of the wind direction from the normal as determined by the lines of equal height anomalies.

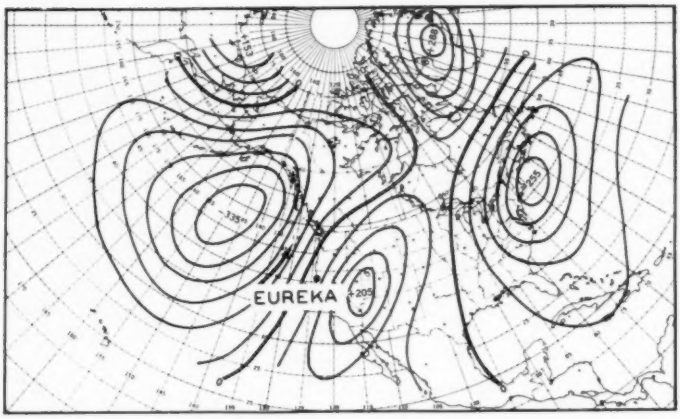


Fig. 2b. 700-mb height departure from normal associated with the warm circulation pattern in Fig. 1b. The arrow indicates the deviation of the wind direction from the normal as determined by the lines of equal height anomalies.

factor in determining Eureka's surface temperature. Furthermore, a good temperature estimate can be derived by forecasting the difference in the magnitude of the height departures from normal at the two key points **even though the values at each of these points may not be exactly correct.** We wish to repeat that this is a highly desirable feature in an objective method, since it is by far easier to predict the overall circulation pattern and the relative differences between points than it is to forecast exact height values at points.

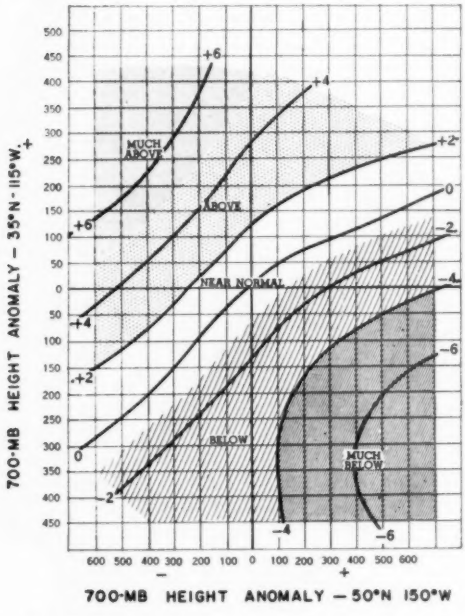


Fig. 3. The graph used in estimating the surface temperatures at Eureka, California, from the 700-mb circulation pattern. The lines are isolines of temperature anomaly. The shaded areas represent the various classes of temperature anomalies.

Statistical procedures were used to determine the optimum areas on the 700-mb chart which must be considered in making temperature forecasts for stations throughout the western United States other than Eureka. It is perhaps surprising that for each of eight widely separated cities which were tested the crucial location is along the 50° north latitude parallel at about 150° west longitude, in the Gulf of Alaska. The second point, usually not quite as significant, shows up for the most part at 35° north and about 115° west, in the southwestern United States.

Using the techniques described for Eureka and Evansville, a set of graphs has been obtained for 21 stations distributed throughout the country. Their reliability has been ascertained by a test of two years of independent data. By means of these graphs, the temperature anomalies were estimated from the observed charts of 700-mb height departure from normal and the resulting temperature patterns were verified by comparison with the observed anomalies. The tests showed that the graphs have definite value in translating circulation patterns into surface temperature anomalies. The objective "forecasts" demonstrated superiority over both subjective temperature forecasting and chance.

As an example of the use of the objective graphs, they will be applied to the circulation pattern shown in Fig. 4. This is the observed 5-day-mean 700-mb chart for December 31, 1949, to January 4, 1950, with the height departures from normal indicated by the dashed lines. Since the heights in the critical area in northwestern Canada are near to or below normal, we would conclude from our discussion of Evansville that the East should not be dominated by cold Canadian air. This is emphasized by the above normal heights at Evansville which are serving to accentuate the flow of warm air in the East. At the same time, the heights at 50° north and 150° west, critical for the western sections of the

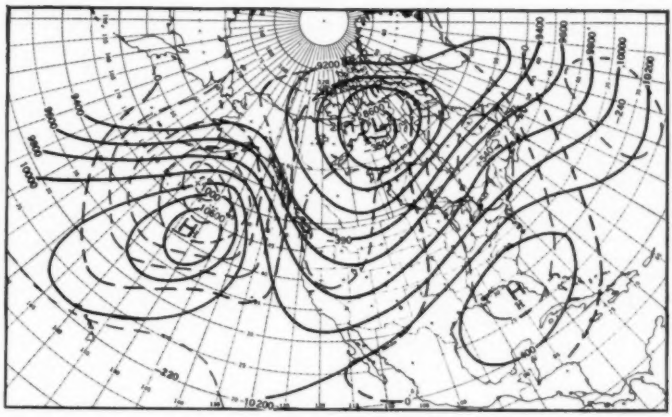


Fig. 4. Observed 700-mb 5-day-mean chart for December 31, 1949, to January 4, 1950. The solid lines denote the height of the 700-mb surface in feet; the dashed lines show the 700-mb height departures from normal in feet.

United States, are far above normal, while negative departures are observed at 35° north and 115° west. Therefore, cold weather is to be expected in the West.

Fig. 5a gives the quantitative temperature anomaly forecasts obtained from the 21 objective graphs with the use of the 700-mb height departure pattern shown in Fig. 4. The temperatures are analyzed in terms of the class limits used in forecasting by the Extended Forecast Section.* Above normal and much above normal temperature anomalies are estimated throughout the eastern and central United States; below normal and much below normal temperatures are indicated in the West. As a test of the method we can compare the temperature pattern obtained objectively with the temperatures **actually observed** during the same period, and illustrated in Fig. 5b.

A comparison of these two figures indicates fairly good agreement. Each shows extremely cold temperatures in the West and extreme warmth in the East, separated by a narrow strip of near normal temperatures. It should be noted, however, that some of the largest discrepancies occur near the dividing zone between the cold and warm temperatures. Such errors are often found when extreme temperature anomalies are observed. One possible way to remedy this is to consider the characteristics of the air masses which are affecting the area prior to and during the period for which the objective temperature estimates are being made. This type of research is currently being conducted.

The objective method of estimating surface temperature has been incorporated into the forecast routine at the Extended Forecast Section by applying the graphs to 5-day-mean 700-mb prognostic charts. It has been found to be of definite assistance in making long-range forecasts.

This article was written by Donald E. Martin. In our next installment we shall discuss the relationships between upper-air circulation and surface temperature pertaining to summertime.

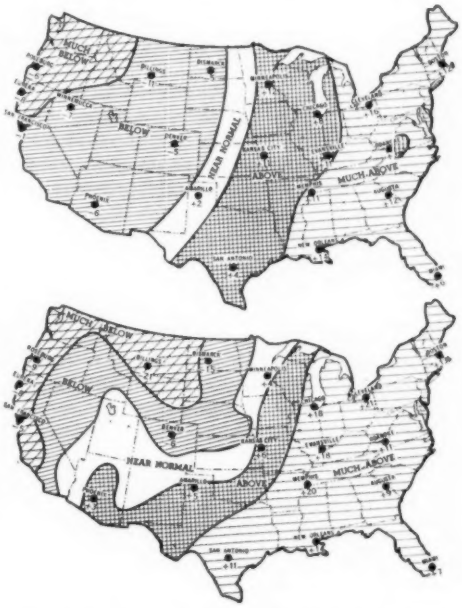


Fig. 5. For the period December 31, 1949, to January 4, 1950, the upper chart shows the estimated 5-day-mean surface temperature anomalies obtained from the circulation pattern in Fig. 4. The lower chart shows what actually happened in that period. Forecast graphs have been completed for each of the stations shown on the chart.

*Class limits are based on a statistical analysis of past records, through which is determined the normal frequency of occurrence of temperatures at various times of the year for different locations. The classes above, below, and near normal are so defined that they each normally occur one fourth of the time; and the classes much above and much below normal, one eighth of the time.

WORKSHOP FOR WEATHERMEN

CONDUCTED BY CHARLES A. LAIRD

How to Construct a Glass-Tube Rain Gage

MOST RAIN GAGES are of the "multiplying" type. That is, a funneling arrangement is used so that the indicated measurement of rainfall is some multiple of the actual amount that has fallen. In the gage described here, 1/10″ on the scale means that .01″ of rain has fallen.

The measuring tube is a piece of glass or pyrex tubing, ½″ inside diameter. Standard glass tubing is not very uniform as to inside and outside dimensions, and it is advisable to go through a stock of glass tubing and measure several sections with a pair of "inside" calipers. Neon sign shops and chemical and drug supply houses are a good source of glass tubing.

In the gage shown in the drawings, a 10″ scale is used. This means that the gage will measure up to 1″ of rain. However, you may make your gage longer if desired. The glass tube should be about ½″ longer than the scale.

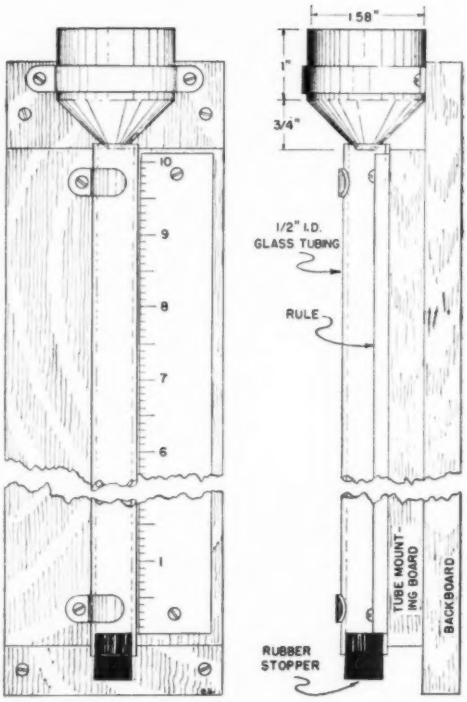
The funnel has a rim 1″ long, to prevent rain from splashing out. Its inside diameter must be as near 1.58″ as you can make it. This gives an effective rain catching area 10 times as great as the ½″ glass tube. You can cut a strip of galvanized iron or copper 1″ wide and 5¼″ long, form it into a cylinder, and lap the ends over ¼″ for soldering. This will make a rim as accurate as it is possible to do with sheet metal. Or, better still, turn the rim on a lathe or have someone do it for you. Solder a 45° funnel on the bottom of the rim with a ¼″ opening at its lower end.

The funnel and tube assembly is mounted on a backboard made of ½″ wood, 4″ wide, the funnel being clamped to it with a ⅜″ metal strip, using wood screws. Allow about ½″ of the funnel rim to stick above the backboard. In front of this mounting board is fastened another, shorter board of the same width. You may glue this board on, or use small finishing nails. The glass tube is mounted on this board, using small metal clamps bent to conform with the tube's curvature. Detail of this construction is shown in the drawings.

A wood or metal rule, divided into inches and tenths, is fastened alongside the glass tube with its zero mark about ½″ above the lower end of the tube. Use a rubber stopper in the lower end of the measuring tube, with its top end at the height of the zero mark on the scale.

All wood and metal parts should have two coats of outside paint to prevent rust and warping. The rain gage may be mounted on a post, using long wood screws. Be sure the top of the funnel rim is higher than the top of the post.

To empty the gage after a rain, merely pull out the rubber stopper, being sure to replace it at the right level at the zero of the measuring scale.



The glass-tube rain gage, its length shortened for clarity (front view left, side view right).

The gage cannot be used during freezing weather, due to the danger of freezing and breakage of the glass tube. You can make a cover for it, or remove it from the post in cold weather.

In the event it is not possible to obtain standard ½″ tubing, or to make the inside diameter of the funnel 1.58″, other sizes of tube and funnel can be used, but a change in the conversion factor will occur. It is most desirable, of course, that this factor be an even integer, but any other factor can be used, for only multiplication by the amount of rainfall in the tube is needed to obtain the actual rainfall. Suppose the tube were to have a ¾″ and the funnel a 2.8″ inside diameter. Square these numbers to find the ratio of the cross-section areas, 0.5625/7.84, or 0.07175, which may be rounded off to 0.072. Thus, one inch of rain in the tube represents about 7/100 of an inch of rainfall.

CLIMATE THROUGH THE AGES

C. E. P. Brooks. McGraw-Hill Book Company, Inc., New York, 1949. 295 pages. $4.50.

HERE is a book that will delight the scientist with a historical turn of mind. Meteorologists share the necessity of most scientists to look toward tomorrow rather than to the events of the past. It is, therefore, a pleasure to find an eminent member of the profession who has turned his sights backwards and through inquiry into the nature of our past climates brought new light to some of meteorology's most pressing present problems.

It is timely that a volume of this scientific stature is at hand to counterbalance the widely publicized "hypotheses" of Dr. Immanuel Velikovsky, whereby he proposes to explain the vague writings of Biblical and other ancient historians by unheard-of astronomical and meteorological occurrences. Advance accounts of his proposals have been published in several leading magazines, and his first book is about ready for distribution. In the solid work of Dr. Brooks, meteorologists will find much ammunition to refute the unfortunately fascinating but extremely unlikely ideas promulgated by Dr. Velikovsky.

This compact volume is based, mainly, on Dr. Brooks' earlier work, **The Evolution of Climate** (1926). Although the general pattern remains the same, many chapters have been rewritten in the light of the research of the past 20 years, and the author states, "It is now possible to present a much more complete interpretation of the changes of climate in the historical period than could be given in 1926."

Thus, the third section of the book deals with the climates of different parts of the world from about 5000 B.C. to the present. Here much independent material from different parts of the world has been gathered, such as data from the annual rings of the big trees of America, the literary and historical records of Europe and China, the levels of the Caspian Sea, the racial movements in Asia, and the floods and low stages of the Nile. After an examination of these, Dr. Brooks states his whole theme:

"These have shown so good an agreement with each other and with such records of solar activity as we possess, that I cannot but feel that the climatic fluctuations portrayed are definitely real and demonstrate the solar control of climate in the absence of disturbing geographical changes."

The first section of the book, in which the factors possibly affecting climate are discussed, is essentially a textbook of meteorology in which some of the "constants" of ordinary usage are treated as variables. One chapter looks into the radiation of the sun and its possible variation through the ages, and another examines changes that may have occurred in the shape and orientation of the earth's orbit to cause cyclic behavior during glacial periods. Throughout the book, the leading problem under discussion is that of the rise and fall of glaciation.

The book's second part applies the principles laid down in the first to the various problems presented by geologic climates. It opens with a comparison — by the method of correlation — of the climatic history of the north temperate and polar regions with the corresponding changes of elevation, land and sea distribution, oceanic circulation, and volcanic activity. The theory of continental drift, so popular in the early years of this century, receives full consideration, and is found wanting as being unnecessary to account for the distribution of past climates.

Dr. Brooks summarizes our climatic fluctuations into four categories. First are the major oscillations, lasting millions of years and caused by the major cycles of mountain building and degradation. Second-order changes lasting thousands or tens of thousands of years may be caused by minor changes in land and sea areas, astronomical cycles, and possible variations in the solar output. Smaller climatic oscillations of periods of a few hundred years seem to be due mainly to variations in the sun's radiation.

In the fourth category and of immediate interest are climatic oscillations lasting only a hundred years or so. These appear to be caused by variations in the general circulation of the earth, and they have no apparent external source. They probably result from the interaction of winds, ocean currents, and floating ice fields; at present we are unable to predict the future course of these changes.

The author is emphatic in ruling out cataclysmic events, such as clouds of cosmic dust, strange stars, or great disturbances of the earth's rotation. The known causes, he concludes, suffice to account for the variations of climate in geological and historical time.

D. M. L.

Weather Exchange

Classified advertisements for this column are 8 cents a word, including address; minimum ad 20 words. Remittance must accompany orders. Write Weatherwise, AWA, The Franklin Institute, Phila. 3, Pa.

FOR SALE: Weather Bureau barograph, Richards type, overhauled, $75.00. Cotton Belt instrument shelter with Greens maximum and minimum and sling psychrometer, $75.00. New 453-B receiver with speaker converted to AC, $25.00. Radio compass receiver converted to AC, 190 to 1700 kilocycles, dusty but new, with speaker, $30.00. Wind direction, Selsyn type with 20-foot pipe, wires, cable, ready to go, home-made but looks like a professional job and cost me more, photos on request, $65.00. Fee and Stemwedel Navy aneroids, like new, $20.00 each, 2 for $30.00. Selling above items separately, or the works for $250.00. Buying a new sailplane. Hollis Button, Valley City, North Dakota.

THE METEOROLOGY OF AVALANCHES — II

(Continued from page 37)

reproduction of a snow crystal. He used this plastic to reproduce a small snow profile. After a little practice it should be possible to make a reproduction of a 150-inch-deep snow profile.

The possibilities of such a technique are tremendous. Permanent records could be kept of the snow, leaving no uncertainty due to different interpretations on the part of observers. The snow profile could be studied in a warm room or even in summer for research work.

The only true avalanche instrument now in use is the *ram*. This measures in kilograms the resistance of the snow to the penetration of the ram's cone-shaped tip. A known weight is allowed to drop on the calibrated rod from a known height. A record of the penetration with each blow is made and the resistance of the snow is thus calculated. When this is done in connection with a dug profile, the ram shows the same layering found by observation, and also shows greater resistance to those layers which the observer finds tougher by touch in the dug profile.

We used this ram to check variations in the consistency of the snowcover adjacent to the protected test ground. The angle and exposure of a slope and its contour all have a very great effect on the cover. With the ram a check can be made to show these differences without digging. Settling of the new snow can also be measured by the calibrations on the ram. The ram is not and never was, as some people think, intended to tell whether or not the snow will slide. But if used properly, it gives a quick, easy way of checking the nature of the snowcover.

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RAINMAKING — PAST AND PRESENT

(Continued from page 26)

whether or not there are sufficient natural nuclei in the atmosphere to induce precipitation. Dr. Irving Langmuir, of General Electric, declared emphatically there are not sufficient nuclei present on most occasions: by proper methods of seeding, injecting nuclei of the right kind at the right place at the right time, the precipitation mechanism can be triggered and the process spread throughout the cloud and surrounding atmosphere by a continuing reaction.

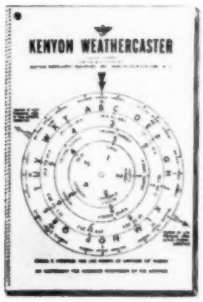
On the other side of the discussion was William Lewis, a Weather Bureau scientist associated with Project Cirrus, a joint U. S. Signal Corps and Office of Naval Research investigation into seeding techniques. Mr. Lewis declared that there are definitely sufficient nuclei in the air most of the time in the form of ice crystals, and the addition of more will not cause or hasten precipitation.

The theory of condensation nuclei was stated as early as 1880 by Aitken, who placed great importance on dust particles. "What a 'hunch' this discovery has given the rainmaker," observed Humphreys 25 years ago. "If you want rain, he tells us, just carry a load of dust with an aeroplane and powder the face of the sky with it; then, presto, behold a cloud with a silver lining. . . ."

In a radio broadcast in March, the past president of the American Meteorological Society, Capt. Howard T. Orville, pointed out that there is an abundant supply of water over the United States as a whole, and that local shortages resulted from exploitation of certain areas without consideration of the available amount of water. Attention to past precipitation records and improved long-range forecasting should help prevent water shortages, he said.

As a result of rainmaking and snowmaking experiments, an entirely new branch of meteorology has now come into being with the fitting designation of cloud physics. It may prove to be the most economically productive of all the weatherman's efforts.

Forecasting Aids



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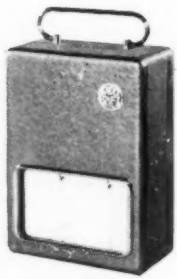

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